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THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

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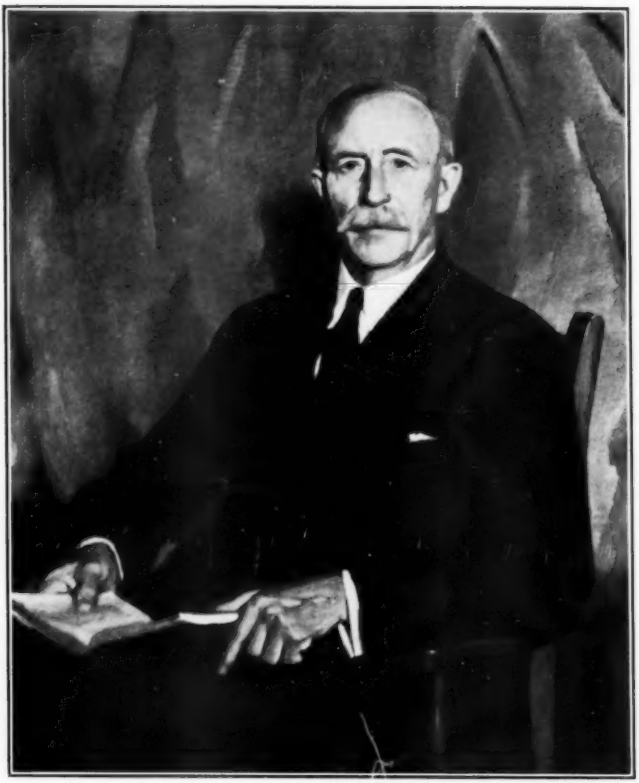
PLATE I



LOUIS BEAUFORT STEWART

Professor of Surveying and Geodesy in the University of Toronto
From a portrait by Charles McGregor

Journal of the Royal Astronomical Society of Canada, 1931.

THE JOURNAL

OF

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PORTRAIT OF PROFESSOR L. B. STEWART

(With Plate I)

Graduates of the Faculty of Applied Science and Engineering of the University of Toronto recently presented to Professor L. B. Stewart his portrait in oils by Charles McGregor, of Toronto.

Professor Stewart in 1888 joined the staff of the School of Practical Science. It had been in existence only eleven years and was not then affiliated with the University of Toronto. Its entire staff consisted of Professor John Galbraith, Dr. W. H. Ellis and Mr. Stewart, together with three fellows, and there were, in the session 1888-89, 57 regular and 11 special students. To-day the Faculty of Applied Science and Engineering has a staff of 95, not counting the members of other faculties which give instruction, and 848 students.

Professor Stewart is an Ontario Land Surveyor, a Dominion Land Surveyor and a Dominion Topographical Surveyor. The examination for the last diploma is very difficult and there are only about five holding it in Canada.

Professor Stewart has travelled in all parts of the country—the Yukon, the Rocky Mountains, about Hudson Bay, the Lower St. Lawrence, and Labrador—being usually engaged on some important government mission. In 1905, when the Dominion Government sent an expedition to Labrador to observe the total eclipse of the sun, Professor Stewart went ahead, by way of a fishing vessel from Newfoundland, to locate the middle of the path of totality at the foot of Hamilton Inlet, about 120 miles from the

I think, therefore, you will have no difficulty in deciding upon which object is Saturn and if you have a good field glass, or better still, a small telescope, you can have a good view of the rings of Saturn during these summer evenings.

While I am not versed in mythology, I have read that in Grecian mythology Saturn was the youngest of the offspring of Uranus, the god of heaven, and Ge, the goddess of earth. The children were somewhat unruly when they grew up, as nowadays, and Uranus, the father, in disgust, hurled them back at the mother, earth. This enraged the earth and she instigated her children to slay the father. When Saturn, the youngest, accomplished this and ruled in the heavens instead, he remembered the prophecy regarding his own death at the hands of his children and resolved to prevent such an occurrence; as his progeny were born he ate them alive. Let us drop the legend there.

When Galileo, the inventor of the telescope, some 300 odd years ago, directed his first instrument to this planet he seemed to see it attended by a satellite on either side. The first telescopes were necessarily crude and imperfect, and rendered distorted images of the heavenly bodies. Galileo described what he saw as "wings on either side bearing the old man, Saturn, along on his journey".

Continuing these observations, Galileo found that though these wings appeared immovable, yet they began gradually to diminish and at the close of the second year vanished altogether. In Galileo's day the heavenly bodies were looked upon as invariable. They were synonymous with perfection and constancy and small wonder, then, that he was horrified at the extraordinary phenomenon he had witnessed in the disappearance of the "wings" of Saturn. He was almost led to think there might be something in the legend of Saturn "devouring his own children".

Let us describe very briefly the planet and the ring around it and see why it vanishes in certain years. Saturn is about 820 times the size of the earth and, like the earth, it receives its light from the sun. It is nearly ten times as far away from the sun as we are and consequently takes much longer to make one complete circuit of the central luminary. As a matter of fact it requires 29.5 years for Saturn to make a complete circuit of the sun.

The planet is surrounded by a thin flat ring. We may liken this ring to a circular sheet of paper, 24 inches in diameter, with a 12-inch hole out of the centre. A toy balloon, 10 inches in diameter, set in the hole would complete the picture. This ring was formerly considered to be solid even though thin, but it is now known to be composed of thousands upon thousands of little particles or moons swarming close together as they move around the planet, thereby giving the appearance of a continuous sheet of matter. The thickness of the ring, represented by the thickness of the paper in the illustration above, is not over 30 miles and the moons which comprise it have diameters even less.

If your telescope is three inches or more in aperture and the night is steady, you will note that the ring is divided into three concentric divisions. Probably you may have difficulty in seeing all three divisions, but you will almost certainly see it divided into two. It would seem as if there were jealousies or ill-feeling among the multitudinous host of the satellites and they have grouped themselves into three main divisions as they journey around the central body of Saturn. The divisions are well seen in larger telescopes as many of our Saturday night visitors at the observatory can testify.

To understand why the ring disappears we have only to remember that twice during its passage about the sun, the ring will be seen edge on from the earth. It then appears as a thin line of light almost vanishing completely. These disappearances occur as just stated, twice during 29½ years, or about once every 15 years. Gradually the ring will open out as it moves on in its orbit and after 7½ years more it will have opened out to its fullest extent. At its maximum phase it is never, of course, seen broadside on, but as if you were viewing it from 28° above or below. Thus the smaller diameter of the ring never appears more than about half that of the longer diameter. It is in about this phase the present summer.

Parallel with the ring you will see markings or belts across the disk of the planet. These are similar to those on Jupiter which I described some little time ago and are simply cloud forms drawn out into streaks by the fairly rapid axial rotation of the planet.

THE MOONS OF JUPITER—MARIUS AND GALILEO

By E. G. Hogg*

Simon Marius

The moons of Jupiter were notable for the argument in favour of the Copernican hypothesis they supplied to Galileo; it is to this astronomer that their discovery is generally ascribed, but there are other claimants to this honour, notably Simon Marius, a pupil of Kepler. "According to Humboldt," writes J. Ellard Gore, "the four bright satellites of Jupiter were seen almost simultaneously and quite independently by Simon Marius at Ansbach on December 29th, 1609, and by Galileo at Padua on January 7th, 1610. The actual priority therefore seems to rest with Simon Marius, but the publication of the discovery was first made by Galileo in his Nuncius Siderius, 1610." As Grant in his "History of Physical Astronomy" calls Marius an "impudent pretender" it has seemed worth while to ascertain what were the actual facts of the case so far as they could be found out after this lapse of time and the enquiry has not been without interest.

Simon Marius was born in Bavaria in 1570; he studied astronomy under Tycho Brahe and Kepler, and in 1604 was appointed Court-Astronomer to the Margrave of Brandenburg-Ansbach. In 1609 he procured a telescope with which he began to study the heavens, and he records that early in the December of that year he observed Jupiter and saw that it was attended by some faint stars, some preceding, and others following the planet, which he thought were in the background of his field of view, and not connected with Jupiter. When, however, later in the month the planet retrograded and the faint stars still accompanied it, he gradually became convinced that they were moving round it just as—according to the Copernican view—the planets circled about the sun. He began regular observations on January 8th, 1610, of the three satellites his telescope revealed; a short time later he acquired two excellent "Belgic lenses," and with the superior instrument he now possessed he discovered a fourth moon on January 22nd, 1610.

*In "Astronomical Notes" of the New Zealand Astronomical Society.

We are now in a position to see how the question of priority stands. Galileo made his first observation of Jupiter on January 7th, 1610, when he noticed three faint star-like objects in proximity to the planet; on the 10th he began to suspect that they might be moons attached to that body; on the following day he became assured that this was the case, and also detected a fourth satellite. He announced his discovery to the world in 1610 in his "Nuncius Siderius." The observations of Marius in December, 1609, and the early part of the following month had convinced him that Jupiter was attended by three satellites; on January 8th he began to take accurate measurements of their positions relative to the planet, and on January 22nd he saw the fourth moon for the first time. An account of his discovery first appeared in 1612 in a work edited by him, called "Frankischer Kalender oder Practica."

So far as priority depends on publication, there can be no doubt that Galileo's claim is secure, but the above recital of the facts of the case will make most readers feel that Grant had little justification for his abuse of Marius. What Galileo thought of the matter we do not know very definitely, but when, later on in the same year, 1610, he found that Venus showed phases similar to those of our moon, he immediately communicated the information to Kepler so that he might run no risk of losing the credit of this discovery.

We may add that later on Marius published a set of tables of the motions of the four moons, and in this he undoubtedly had priority; he also discovered that Mercury showed phases similar to those of our moon, and thereby added weight to the argument of Galileo in support of the Copernican hypothesis. He died at Ansbach in 1624. He did much useful pioneering work in astronomy, but his fame was entirely overshadowed by that of Galileo, and his name is now known only to those whose curiosity leads them into the by-paths of the subject.

The Satellites of Jupiter

Jupiter is accompanied in its orbit round the sun by a magnificent moon-system, of which there are no fewer than nine members. We have described how the telescope in the hands of Galileo and

Marius revealed four bright ones in 1610; it was not until 1892 that a fifth was discovered visually by Barnard; the remainder were detected photographically, the sixth and seventh by Perrine at the Lick Observatory in December, 1904, and January, 1905, respectively, the eighth by Melotte at the Greenwich Observatory in 1908, and the ninth by Nicholson in 1914. While the first seven discovered move round Jupiter in the same direction as that body rotates, the two last found, which are also the outermost ones, revolve about their primary in the retrograde direction.

The moons first discovered were called by Galileo the "Medicean stars" in honour of his patron, the Grand Duke of Tuscany; they are now known as I., II., III., and IV., the one nearest to the planet being styled I. These four would all be visible to the naked eye on a clear, dark night, if they were not so close to their primary; III., the largest and brightest, would be of the fifth magnitude, and therefore an easy object to see. Their times of revolution are $1\frac{3}{4}$ days, $3\frac{1}{2}$ days, 7 days, and 16 2-3 days respectively, and their distances from the planet range from 262,000 to 1,169,000 miles.

The diameters of the four are respectively 2460, 2000, 3540, and 3350 miles; it will help us to form some idea of the size of those bodies if we recall that the diameter of our companion is 2160 miles, while the diameters of the planets Mercury and Mars are 3030 and 4230 miles respectively. The largest of the Jovian moons, III., if placed beside Mercury or even Mars would exceed them in brightness and thus appear as a very respectable planet. From the markings shown under favourable conditions, it appears certain that the third satellite behaves like our moon and always keeps the same face towards its primary.

Polar Caps

White polar caps have been seen on the third and fourth moons by Professor Barnard and Mr. Douglass. The former says they are "exactly like those of Mars. Both caps of the fourth satellite have been clearly distinguished, that at the north being sometimes exceptionally large." Barnard and Douglas stand in the very front rank as observers, and, therefore, their testimony as to these caps may be accepted with confidence, though we may find it difficult to provide a satisfactory explanation, especially in the case of satellite IV.

These two moons are, as we have seen, of considerable size, much larger in fact than our companion, but their densities are low, that of III. being 2.2, and that of IV. 0.6; hence, while the mass of II. is about double that of our moon, that of IV. is only about three-quarters.

The existence of caps on a planet or satellite, which vary in size, and sometimes are entirely absent, shows that the body in question possesses an atmosphere surrounding a solid interior and that the gravitational forces at the surface of such interior are sufficiently powerful to prevent the escape of the atmosphere into space. We have good reason to believe that our moon has been unable to retain the atmosphere with which it was in all probability endowed when in a molten condition, and it is difficult to see how satellite III. can have escaped a similar fate. From the exceptionally low density of satellite IV. it seems reasonable to infer that it is almost entirely gaseous, in which case we are at a loss to understand how, even if it could maintain its coherence, it could show polar caps. We have here another of the many interesting problems presented by Jupiter, which will no doubt be solved in due time.

The Remaining Satellites

The moons with which we have dealt are almost of planetary dimensions; the others are all very small. No. 5, which is probably about 75 miles in diameter, lies between I. and Jupiter, and revolves about its primary in just less than twelve hours. Nos. 6 and 7 are about 100 and 40 miles in diameter, respectively, and perform their revolutions about Jupiter in 250 and 260 days, respectively. The remaining two move, as we have said, round their primary in the retrograde direction; they are extremely small and their detection on the photographic plate was no mean feat. Compared with the other moons, they lie at great distances from Jupiter and it has been suggested that while the other moons have been generated from their primary by some evolutionary process which we do not as yet fully understand, the two outermost ones are asteroids or minor planets, whose orbital movements have brought them into such positions relative to Jupiter that they have been captured by that body and so added to its normal family—an interesting theory to which we hope to recur on some future occasion.

THE VALUE OF SCIENTIFIC RESEARCH

By C. S. Beals

INTRODUCTION

A question frequently asked of anyone connected with an astronomical observatory is "Of what use is astronomy?" It is a somewhat difficult question to answer. To point out the necessity of precise astronomical observations for the determination of time, for the purposes of navigation and for geodetic surveys is only avoiding the real issue, since it is well known that none of the larger and more modern astronomical observatories were built for these purposes. The work done at these institutions consists almost entirely of pure scientific research, conducted solely for the purpose of extending scientific knowledge and with no immediate practical end in view. Any arguments advanced to justify large expenditures of money and of human effort in this type of work must necessarily be similar in nature to arguments put forward in support of other branches of pure scientific research. Indeed, recent discoveries in physics and astronomy have served to emphasize the inter-relation of the sciences. Physics and astronomy are fundamentally one and the same subject. A knowledge of mathematics is essential to the study of either. Between physics and chemistry there is only an arbitrary division line. The same is true to a lesser extent of chemistry, biology and geology. As a consequence, the present article, while intended primarily as an apologetic for astronomical research, will deal actually with science as a whole and the benefits to human life for which it has been responsible.

Science in Early Times

Reading accounts of the speculations of early scientists one is at times inclined to marvel at the accuracy of the intuition which led them to suggest hypotheses, such as, the atomic theory of Democritus and the astronomical theories of Aristarchus, which could not then be verified but which later were shown to be in

substantial agreement with the facts. On the other hand there is the undoubted fact that, in endeavouring to explain natural phenomena, they usually took the wrong turning. This is to be attributed partly to the difficulties of the problems which they attempted to solve but principally to the fact that they did not fully realize the necessity of experiment as the final test of scientific truth. There were, to be sure, some experimentalists, including Aristotle, for whose researches in biology his patron Alexander is said to have donated a sum of 800 talents (equivalent to $4,000,000 in modern purchasing power) and Archimedes of Syracuse, who discovered the principles of buoyancy while taking a bath. These were exceptional cases, however, and the slow progress of science in early times was undoubtedly due in large measure to the lack of adequate experimental checks on would-be scientific speculation.

In spite of this serious handicap, the ancient scientists have a number of very solid achievements to their credit. These include the work of Aristotle in biology, the invention of plane geometry by Euclid, the founding of plane and spherical trigonometry by Hipparchus, the discovery of the principles of buoyancy and of certain principles in mechanics by Archimedes, and the discoveries in physiology and in medicine made by the Alexandrian school. Probably astronomers would be inclined to add the astronomical system expounded by Ptolemy, which explained the facts of the solar system as they were then known, even though it has since been superseded by the system of Copernicus and Kepler.

It is scarcely necessary to point out the usefulness of these discoveries, and whatever value we place on the modern achievements of science a due share of credit should be given to these early pioneers who began the process of observation, speculation and experiment of which the science of today is the final outcome.

Rise of Science from the Renaissance to the Modern Age

During the period from the beginnings of the Renaissance to the 19th century, science showed a comparatively continuous and rapid development. Even before the Renaissance, Roger Bacon had foreshadowed the beginning of modern research by his insistence on the use of mathematics in conjunction with the other sciences

and on the necessity of experiment to verify scientific speculations. He was followed by such great men as Leonardo da Vinci, Copernicus, Francis Bacon, Kepler and Galileo who prepared the way for the great advances in physics and astronomy inaugurated by Sir Isaac Newton in the 17th and 18th centuries.

In the six hundred years between the 13th and the 19th centuries, science was not put to any very important commercial or practical uses, but it was during this period that it exercised what was perhaps its most important and far reaching influence on human thought. The beneficial effects of this influence were shown in the freeing of the minds of the people from superstitious ignorance, from dependence upon traditional beliefs and habits of thought, and from the tyranny of ecclesiastical authority.

During the middle ages belief in magic, witchcraft and evil spirits was almost universal. Every manifestation of natural forces was attributed to supernatural agencies, and the air was filled with demons who constantly exerted sinister influences on human affairs. Belief in miracles was general, being fostered by the clergy, and no account of a miraculous occurrence was too preposterous to command belief. Alchemy was practised and the rulers of nations employed astrologers whose duty it was to predict the course of future events from the aspects of the heavens.

Some of these beliefs were relatively harmless but others, notably the belief in witchcraft, were the result of morbid terror of unseen supernatural forces and were the cause of an appalling amount of human suffering and death. Hundreds of thousands were put to death as witches during the period under review. The most diabolical tortures were used to exact confessions from witches and the most iniquitous and false legal processes were used in their prosecution. It is pleasant to record the fact that there were some brave men whose names include those of Cornelius Agrippa (early 16th century), John Weyer and Reginald Scot (16th century), and Father Spee, a Jesuit priest (17th century), who risked their lives by publicly protesting against the mania, but they were able to make no impression on the mad superstition of their time. A decline in the belief in witchcraft only came when scientific knowledge was sufficiently far advanced to demonstrate that events in the realm of nature could be explained by laws that

are constant and invariable and not subject to the caprices of supernatural beings. The evidence, apparently so convincing, on which many witches were condemned could not stand before even the most elementary scientific investigation, and the advance of science finally rendered alike ridiculous the claims of witches to supernatural powers and the accusations directed against them.

With the decline in the belief in witchcraft went the belief in many other equally irrational but less harmful superstitions. People became gradually less inclined to credit accounts of miraculous occurrences and more ready to investigate the authenticity of the supposed miracles. The belief in alchemy became less as knowledge of chemistry became greater. Astrology was held in lesser esteem as astronomical knowledge advanced and while there are still numerous ignorant or credulous people who have faith in a horoscope, any serious belief in astrology by those who were in a position to test its claims, died with the 17th century.

Another service which science performed during this period and one which is intimately related to the overthrow of superstitious beliefs has to do with what might be termed the medieval attitude of mind. This attitude, which is not entirely unknown in the present day, was characterized by extreme conservatism, bondage to tradition, worship of the past, and a fierce antagonism toward change or progress. All arguments were settled by appeals to authorities of a former day. Every attempt to think things out in a rational manner was met by a blank wall of ignorance, intolerance and fanatical hatred of innovation. The promulgation of beliefs on all subjects, science included, was the exclusive function of the church and anyone venturing to advance a belief contrary to the theological tenets of his day was in no inconsiderable danger of his life.

It is easy to see how inimical to scientific progress or to progress in any department of human thought were such habits of mind as these. It is also easy to see that the results of scientific observations and experiments provided the most convincing demonstration that the traditional view was not always the correct one. If the work of Copernicus and Kepler placed beyond reasonable doubt the fact that the sun rather than the earth was the centre of the solar system, while the authorities of the past and the fathers of

the church supported the opposite view, then so much the worse for the authorities and the fathers. Similarly with the discoveries of Newton and Galileo. The results of their labours showed that there were other ways of gaining knowledge than by digging in the past. Experiment and the untrammeled exercise of the intellect were shown to be productive sources of truth in the field of science, and the conclusion was inevitable that methods which had proved valid in scientific investigations should hold good in other branches of knowledge. There is little doubt that the splendid results which followed the methods of free enquiry and experiment in the field of science did more to advance a spirit of tolerance and intellectual freedom than any other single influence of the time. This new spirit in the world of thought is the best of all gifts which science has brought to the world: and while its most spectacular effects must be looked for in the period when Europe was emerging from the darkness of the middle ages its influence is progressive and has been responsible for continuous advances in human thinking up to the present day.

Practical Applications of Science

The industrial revolution of the 19th century represented the first result of the application of science to industry, and all are familiar with the increasing number of applications which science has had in the fields of industry and commerce since that time. Modern methods of transportation, communication and manufacture are completely dependent upon the results of scientific discoveries. A modern industrial state such as England or the United States would be utterly unable to support its present population without the aids which science has provided in the struggle for existence. All this is well known and clearly recognized even by those who are not primarily interested in science. What is perhaps less well known and which should bear emphasis is the fact that those discoveries in science which have had the most universal application in commerce and industry, and which have proved to be of the greatest practical benefit, were made as a result of researches conducted solely for the purpose of extending scientific knowledge and with no immediate practical object whatsoever.

The history of these discoveries is exceedingly interesting, but the scope of the present article will allow for the mention of only one or two of the most important.

The science of mechanics, which forms the basis of modern engineering practice, while not unknown to the ancients, was brought to its present highly developed state mainly through the purely theoretical investigation made by French and English mathematicians and physicists of the 18th and 19th centuries. The discovery of current electricity also was made as a result of researches conducted solely for the object of enlarging scientific knowledge. The same may be said of the discovery of electro-magnetic induction by Faraday, the work of Maxwell and Hertz on electro-magnetic waves, the discovery of X-rays by Röntgen and the investigation of the photo-electric effect by Einstein. The far-reaching importance of these discoveries in electricity becomes obvious when we realize that they have been directly responsible for the dynamo, the electric motor and all other forms of electrical machinery, for telegraphy, telephony and wireless communication, for the use of X-rays in medical practice and for the application of photo-electricity to many practical problems including the production of talking motion pictures.

Many other similar instances may be cited since the present discussion has been confined to physics and astronomy, and nothing whatever has been said about the innumerable useful discoveries in chemistry, biology and geology; but these examples should be sufficient to illustrate the practical benefits resulting from pure scientific research. The experience of the past and the fact that new applications are daily being found for science in industry make it a practical certainty that many present day researches, however far they may appear to be removed from the practical sphere, will in the future find useful applications in daily life. And even though few would venture to suggest that this is the principal *raison d'être* of science, the prospect of future practical and commercial benefits alone should provide sufficient justification for the greater part of the research being conducted in the present day.

CONCLUSION

In the preceding paragraphs an endeavour has been made, first, to indicate the influence of science in dissipating the darkness of ignorance and superstition and in advancing the cause of intellectual freedom; secondly, to show the value of research in increasing industrial productivity and drawing the corners of the world together by modern methods of transport and communication.

These achievements are surely sufficient to place scientific research in the forefront of useful and valuable human activities. And yet if only these aspects of science are considered we are likely to miss some of its real significance and to miss entirely the motives which actuate scientific workers. These motives have to do with an intuitive appreciation of the value of scientific knowledge for its own sake, the significance of which is somewhat difficult to put into words. Some idea of the sources of this appreciation may be suggested by referring to the unique character of many of the concepts with which the student of science becomes acquainted and the power which they possess of arousing his wonder and admiration; to the powerful methods of analysis at the disposal of the scientist which enable him to control conditions in an experiment and gain information in a manner that seems almost miraculous; and finally to the harmony and obedience to natural law which science has shown to exist not only among all living things and inanimate objects on the earth but which extends to the farthest depths of space and may be clearly discerned in bodies such as the spiral nebulae which are almost inconceivably distant from the earth.

Unlike works of art, the achievements of science do not make any direct pleasurable appeal to the senses. And yet it is an undoubted fact that the student or the research worker finds in the complex structure of modern science an unfailing source of intellectual enjoyment and mental satisfaction which are closely akin to aesthetic pleasure. To its devotees, science no more requires justification than does music, literature, painting or any other form of activity which enriches and gives value to human existence.

PLATE II

METEOR CRATER, ARIZONA

From an air-photograph by James Stokley, of "Science Service", and kindly furnished by him

NATURE AND FATE OF THE METEOR CRATER BOLIDE*

(With Plate II)

By Herman L. Fairchild

The impact origin of Meteor Crater, Arizona, is an accepted fact. The fate or disposition of the colliding body is yet undetermined, and is a very interesting problem in cosmic science.

Through many years of exploration, with large expense, the Barringers, father and sons, have collected and published a mass of surprising facts about the crater and its associated meteoric materials. The data, however, have not been marshaled to attack the question of what has become of the greater part of the meteor, excep to sustain the theory that the mass lies buried under the south wall of the crater[1]

The problem of the fate of the meteor involves not only the physical and chemical properties of the discovered meteor fragments but the nature of other meteorites. There are also involved most of the features of the crater and the characters of the rock strata which were disrupted.

Canyon Diablo Siderolites

The meteoric irons known as Canyon Diablo, from the near-by creek and canyon, have been gathered from the desert plain about the crater to the number of thousands and distributed to institutions all over the world. Because of their number and wide distribution, their inclusion of minute diamonds, their genetic relation to the unique crater and their remarkable chemical and physical characters they are the most interesting and instructive of known meteorites. The facts concerning these irons should give some clue to the character and fate of the giant bolide of which they were a part.

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*From *Science*, November 7, 1930. The author is Emeritus Professor in the University of Rochester.—Editor.

[1]See article by D. M. Barringer, Jr., in the *Scientific American* of July, August and September, 1927. A list of the more important writings is given in Science, *69*: 485-487, 1929.

averaging 120 feet high above the plain, appearing from a distance and from the Santa Fé Railroad as a range of low hills, consists of the dislodged Kaibab limestone and the crushed Coconino sandstone. This lower formation was affected to its base and largely reduced to dust. Some portion of the kinetic energy in the colliding body was suddenly changed to short-wave vibrations which shattered the individual sand grains. The resulting dust, of angular, crystalline quartz, is of such microscopic fineness that 55 per cent. will pass a 200-mesh sieve. Masses of the rock which to the eye appear as firm sandstone will crush to powder under hand pressure.

(4) If the meteor was largely brittle material, as will be claimed below, it was also shivered. The matter of temperature applies here; also noted later.

(5) Production of intense heat. Theoretically this was inevitable. Clear evidence is found in masses of the Coconino sandstone altered by fusion to "silica glass" or lechatelierite. This required a temperature of 1,400 to 1,800 degrees Centigrade.[2]

Further proof is found in rock fragments that carry brown and green stain from vaporized nickel-iron.

Reaction and Explosive Effects

The huge crater was the product of mechanical reaction. The expulsion of rock was partly by the elastic reaction of the compressed strata with its included air, but largely from water expansion.

The sudden compression of the rock strata to a depth of 1,250 feet involved the air which was in the upper strata and the water which saturated the deeper strata.

Standing water deposits, ninety feet thick in the crater floor, consist of marl and peat of organic origin and sand and clay washed in from the basin walls by the "cloud-burst" precipitation of the desert climate. The height of the standing water in the basin shows that the strata were filled with air and water to the depth of 450 feet and below that were entirely saturated with water.

[2]See article by A. F. Rogers, *Amer. Jour. Science*, March, 1930.

As disruption of the rock reached to the base of the Coconino sandstone, 1,250 feet below the land surface, it follows that 800 feet of the porous sandrock, the affected thickness below the later lake level, supplied water for the steam explosion.

In his examination of the crater in 1892, Mr. Gilbert recognized the explosion phenomena, but interpreted them as volcanic. It may be noted that if the explosion had been from subterranean heat this would have involved the porous strata far and wide, and hot-water or fumarolic phenomena would have subsequently occurred for, perhaps, centuries.

The elastic rebound of the compressed rocks and the included air, and the explosive expansion of the suddenly generated steam produced enormous mass movement. This was the expulsion of the meteor itself and of rock material to the depth of 540 feet and over an area three fourths of a mile in diameter.

The size of the crater does not directly indicate the size of the bolide. It is a problem of two indeterminate factors, mass and velocity.

Physical State of the Meteor

The temperature of the meteor is a factor of some importance. To the degree that its internal temperature was low the mass was correspondingly brittle, whether iron or mostly stone. If the body had suddenly arrived from extra-solar space, as a casual visitor to our planetary system, it probably had very high velocity, and was intensely cold. And even if it had been aimlessly wandering with some relation to the sun it probably had very low temperature and a velocity not less than that of the observed meteors.

The violent impact which produced so great effect on the earth must have shattered the bolide, whatever its velocity, temperature and substance. If it was largely stony material as all the facts appear to indicate, the stone was shivered to dust and swept away in a cloud of vapour, in which case only the included, nodular masses of iron-alloy are the existing remnants.

The walls of the crater have receded somewhat under the storm-wash of many centuries, and the débris has produced the talus slopes, giving the concave profile to the basin. The talus and the

ninety feet of water deposits have buried any meteor fragments which fell into the basin. But many fragments of the hydrated iron, to be described, have been found in the ring of débris topping the walls. And Brandon Barringer writes that it has been found beneath the talus and against the south wall.

Relations of the Irons to the Parent Body

There is no doubt that the thousands of nickeliferous irons found over the desert were associated with the huge bolide. The question is—how did they acquire such dispersion? Were they detached companions of the main body, or are they projected fragments of the disrupted mass?

Dr. O. C. Farrington writes that some specimens of the C.D. irons in the Field Museum have surface features which prove that they fell as individual units. This would indicate that the great bolide did have some free associates, as might be expected. But the fact that the great majority of C. D. irons have irregular forms, with no superficial features produced by atmospheric friction and heat, argues for their inclusion in other material, either as detachments or as an integral part of the great meteor.

If the C. D. irons found over the desert, through a radial distance of four miles, were loose adherents of the central mass, or if they had become detached by the resistance of the earth's atmosphere, then they formed a group some eight miles in diameter. And as distinct units, with original velocity like that of the parent body, the larger ones, with weight of many hundred pounds, should have produced individual craters or pittings in the ground surface. Furthermore, if the typical C. D. irons were only non-oxidizable portions of once larger masses (as some of them certainly are) such larger bodies would have had even greater energy for production of individual craters. If the great bolide buried itself under 1,400 feet of solid rock then the detached units should have behaved in similar manner. But no such pittings of the desert have been noted. Of course, in time the "cloud-burst" storms and high winds of the desert region would obliterate the pittings by filling and such irons as were imbedded would be entirely or partially buried. But all information is to the effect that all the

thousands of collected irons lay exposed on the open surface of the desert.

In this dilemma one suggestion is that the detached units did not imbed themselves but rebounded from their craters.

The iron nodules which were inclusions in the disrupted bolide, and were projected by the explosive reaction, had momentum only sufficient to carry them, like a shot from a mortar, to their positions on the plain. Fragments of the disrupted rocks are reported to lie two miles from the crater. Unfortunately, no facts are available as to the characters of the irons in relation to their distance from the crater.

Physical and Chemical Characters of the Irons

The most interesting and important element in this study is the chemical constitution of the irons. Along with the typical C. D. irons there is at least one other variety. The C.D. type is the unoxidizable and resistant irons which have lain on the desert for a great length of time. They are clearly of nodular character. They generally bear no evidence of frictional passage through the air, but do have the surface features, the irregular shapes and the cavities and perforations of nuclei or enclosed accretions. They are the unoxidized and undecomposed segregations out of larger masses of vanished material. The only doubt is whether the enclosing mineral was decomposable iron or was a stony matrix.

The composition of the permanent, C.D. irons is, by percentage: iron, 92; nickel, 6; some carbon, with minute diamonds; and small amounts of platinum, iridium, palladium, phosphorus, cobalt and copper.

Associated with the easily recognized meteoric irons was a considerable amount of limonite or hydrated iron. During early exploration this was neglected, under supposition that it was derived from the limestone of the desert surface. Barringer noted that larger fragments had a laminated structure and he called it "iron shale." Later, subspherical masses with concentric lamination were found, especially in excavations in hills of débris, and he called these "shale balls." Then it was observed that some of these masses had a green stain, and chemical examination revealed

that they contained the nickel and rare elements of the C. D. irons, and, in addition, chlorine.

A specimen of the meteoric iron, supposed to be the typical C. D., in the Meteor Crater exhibit in the University of Rochester Museum in the course of years disintegrated to powder. If this is another variety of the decomposable iron or if it would have produced the "iron shale" form had it been exposed to open weather is unknown. But it emphasizes the perishable nature of some of the meteorites.

Another important discovery is that nodules of the unchangeable or typical C. D. iron are found in the shale balls. Also, that the decomposable, chlorine-bearing iron is occasionally found in the C. D. irons.

The intimate association of decomposable and of permanent iron clearly explains the cavities, holes and perforations in many specimens of the C. D. meteorites. And a similar cause is suggested for the cavities and perforations in the iron meteorites of other finds, for example, the great Willamette, in the American Museum.

The Arizona Bolide a Stony Meteor

The doubt concerning the Meteor Crater visitor is whether it was wholly meteoric iron or was a larger body of stony composition, with iron-alloy inclusions, in other words, was the meteor of iron, with smaller size, of high density and with high veocity, or a larger body of stony substance with iron inclusions, of less density and perhaps with less velocity?

Our ignorance as to the source of meteors and comets does not justify the assumption that great masses of iron alloys, up to 400 feet in dimensions, could not exist, or are not formed in some planetary bodies or in dead suns, or that they may not exist deep within our globe. However, present knowledge of terrestrial and cosmic processes does not suggest the formation of such massive metallic bodies.

The early suggestion that the mass of the bolide might have been mostly stone, instead of metal, has been ignored because no stony material foreign to the local rocks has ever been found, although diligently sought by S. J. Holsinger, who conducted the

early studies. But when we recognize the perishable nature of stony meteorites any such material should not have been expected.

The stony meteorites are exceedingly varied and complex in both composition and structure and subject to easy decay by atmospheric agencies. In consequence of this the "finds" of stony meteorites, or their discovery apart from visible "falls", are exceedingly rare. The "finds" are practically all of resistant nickel-iron. In his book on "Meteorites" (1915), Dr. O. C. Farrington states that of 350 falls only ten were of iron. But if the stony meteorites are thirty-five times as numerous as the iron, and yet quite wanting among the finds, it clearly shows their perishable nature. It may also be possible that some of the ten irons included in the 350 falls had quickly lost their brittle and ephemeral matrix before they were located.

The Arizona visitor arrived centuries and perhaps thousands of years ago, and time has been amply sufficient to destroy all the mass except the imperishable iron nodules and some of the chlorine-bearing iron.

It should also be noted that the spasmodic precipitation of the arid region has favoured the washing-away of the products of decay, even if these were not all soluble. Doubtless a great quantity of pulverized rock, both limestone and sandstone, was spread widely over the plain. But this has been removed by solution and storm-wash of the torrential rains. The elevated rim of the crater prevented inwash from the surrounding desert.

All the facts concerning the C. D. irons clearly indicate that they were inclusions or nodules of resistant nature, inclosed in some kind of perishable material. And some of that matrix was chlorine-bearing iron.

The rotund or globular form of some of the "shale balls," the decomposable irons, strongly suggests that they also were only concretionary masses in a matrix of other substance. That substance could have been only the stony materials of which most known meteorites are composed. It may not be claimed that because of its greater size the Meteor Crater meteorite was entirely different in source and nature from all other celestial immigrants.

All the facts relating to meteorites in general, and the Meteor Crater bolide in particular, along with the theoretic probabilities,

support the view that the Arizona visitor was a very large stony mass with metallic inclusions.

The stony matrix was brittle, even if without very low temperature, and it was shivered by the impact mostly or wholly to dust. And this was thrown high in air, and, borne by the steam cloud, was disseminated far and wide, and any large fragments were quickly destroyed by decomposition and hydration.

This conclusion regarding the C. D. irons may imply that many others, if not all, of the known iron meteorites, even the largest, were originally inclusions in perishable matrix. The irregular, angular forms, perforations and characterless surfaces were probably produced by their imbedding as nodules or accretions in other materials. Only the irons which have traversed our atmosphere after losing their protective covering exhibit some frictional and flowage surfaces.

In the above study no estimate has been made as to the kinetic energy resident in the bolide, and the explosive effect has been attributed mainly to the water and air held in the rocks. But if the meteor was large, with high velocity and high density, the impact might have produced sufficient heat to vaporize both the meteor and the crushed rock. And more probably such would have been the case if the bolide was wholly or largely nickel-iron.

In such case the metallic vapour, with terrific expansion in all directions, should have coated all the surviving rocks with a green stain. The absence of such stain is another argument for a stony meteor.

If the meteor was dissipated in vapour then the thousands of C. D. irons found on the desert could not have been part of the main body. With or without enclosing matrix they had become detached from the central mass by atmospheric friction, and so far separated, and perhaps laggard, that they escaped the grand smash-up.

MORE ABOUT PLUTO*

By Henry Norris Russell

Ever since the discovery of the new planet Pluto it has been eagerly observed at many places. More than a hundred accurate observations of its place in the heavens have been secured, and from these a rich harvest of knowledge has been reaped. The numerous observations of March, April, and May improved our knowledge of the orbit so much that, figuring backward, its position in past years could be calculated and images of the planet, in some cases very faint, were thus identified on photographs taken at Uccle, Belgium, in 1927, at Yerkes in 1927 and 1921, and at Mount Wilson in 1919. With these available the observed arc of the planet was multiplied twenty fold.

The calculations of Crommelin in England, and of Bower and Whipple in California, based on this fuller material, agree closely and leave no doubt outstanding about the main characteristics of this most interesting object. First and foremost the claim of the newcomer to rank as a planet is decisively confirmed. Though the eccentricity and inclination are greater than for any of the eight principal planets which were previously known, they would pass as moderate among the asteroids and there can be no hesitation in assigning the new body to the ninth place among the sun's more important attendants. There is nothing cometary about it at all; its orbit is far too near a circle and it is eight or ten times as far away as the distance at which even the brightest comets fade out into complete invisibility.

The early calculations which indicated a highly eccentric orbit turn out to have been upset by a small error—only three seconds of arc—in one of the earliest photographic observations, made with a telescope of comparatively short focus and a long exposure. How such a small departure from exactness may be enormously magnified by the process of calculating an orbit was explained last month. In the second place the orbit, now that we know it, is found to be so similar to that which Lowell predicted from his

*Reprinted by permission from *Scientific American* for December, 1930. Each month an article by Professor Russell appears in that magazine.—*Editor.*

calculations fifteen years ago that it is quite incredible that the agreement can be due to accident. Setting prediction and fact side by side we have the following table of characteristics:

	Predicted	*Actual*
Period	282 years	249.17
Eccentricity	0.202	0.254
Longitude of perihelion	205°	212°30′
Perihelion passage	1991.2	1989.16
Inclination	about 10°	17°9′
Longitude of node	not predicted	109°22′

Lowell saw in advance that the perturbations of the latitudes of Uranus and Neptune (from which alone the position of the orbit plane of the unknown planet could be calculated) were too small to give a reliable result and contented himself with the prophecy that the inclination, like the eccentricity, would be considerable.

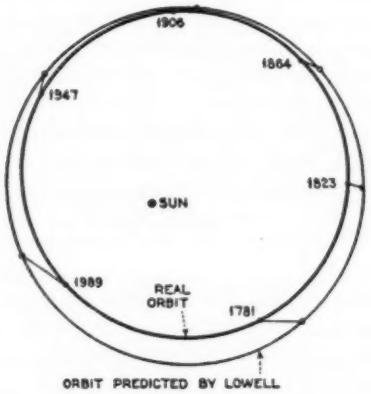

Fig. 1.—Actual and predicted orbits.

For the other four independent elements of the orbit, which are those which Lowell actually undertook to determine by his calculations, the agreement is good in all cases, the greatest discrepancy being in the period, which is notoriously difficult to determine by

computations of this sort. In view of Lowell's explicit statement that since the perturbations were small the resulting elements of the orbit could at best be rather rough approximations, the actual accordance is all that could be demanded by a severe critic.

Even so, the table does not tell the whole story. Figure 1 shows the actual and the predicted orbits, the real positions of the planet at intervals from 1781 to 1989, and the positions resulting from Lowell's calculations. It appears at once that the predicted positions of the orbit and of the planet upon it were nearest right during the 19th century and the early part of the 20th, while at earlier and later dates the errors rapidly increased. Now this (speaking broadly) is just the interval covered by the observations from which the influence of the planet's attraction could be determined and, therefore, the interval in which calculation could find the position of the planet itself with the least uncertainty.

In the writer's judgment this test is conclusive. If someone should maintain that a calculation based on wholly insufficient data (and hence physically meaningless) might by some strange bit of luck result in predicting all four of the important elements of the orbit with the relatively small errors shown above, he would still have to account for the fact that the outstanding errors are so *adjusted* that their influences partly counteract one another and bring about the closest agreement of prediction and fact—just at the time when a genuine prediction, based on physically significant data, would have behaved in the same way!

It may be remembered that substantially the same thing happened in the case of Neptune. Both Leverrier and Adams had assumed that the distance of the unknown planet agreed with Bode's "law", and had therefore taken it much too great. Their calculations made the orbit considerably eccentric (though it is really very nearly circular) but this spurious eccentricity brought the predicted orbit toward the sun in the region where the planet actually lay at the time, and went far to undo the error of two original assumptions. They still had the distance too great, however, and the predicted mass of Neptune was therefore considerably larger than the real value. There were some critics then who maintained that these discrepancies showed that the discovery of Neptune was only "a happy accident" but it has long been acknowl-

edged that these critics were wrong, and the full credit for the great triumph of mathematical analysis has gone where it deserved to go.

History seems this time to have repeated itself closely, except in one tragic detail—Percival Lowell did not live to see his prediction thus fully confirmed. In only one particular was he seriously wrong—he overestimated the apparent brightness of the planet more than ten fold. Several causes probably contributed to this. Pluto is somewhat nearer to Uranus and Neptune than he supposed, hence a small mass would suffice to produce the observed perturbations. Within a year or two—perhaps sooner—someone will doubtless make the necessary calculations and determine the mass of the actual, rather than the predicted, planet. We may guess that it will turn out to be four or five times the earth's mass, instead of six. Even so, it is evident that the planet must be of high density and its surface of surprisingly low reflecting power. But speculation on these matters may well be postponed until observations with the greatest telescopes, under the best conditions of seeing, which will undoubtedly be made this winter, tell us more about the planet's actual diameter.

The relations between the orbits and motions of the new planet and those of Uranus and Neptune are curious enough to deserve mention. According to Bower and Whipple the mean distance of Pluto from the sun is 39.60 astronomical units (we may note in passing that this is close to the distance predicted by Bode's "law", 38.8, for the next planet beyond Uranus, but we will be wiser if we attempt no explanation). This puts the new planet, on the average, about 900,000,000 miles farther from the sun than Neptune But the eccentricity is so great that the distance at aphelion is 49.7 and at perihelion 29.55—which is less than the perihelion distance of Neptune (29.82). If the two orbits were in the same plane they would intersect and there would be a chance of a collision. But the high inclination of Pluto's orbit keeps him well out of danger.

Figure 2 shows the orbits, Pluto's being projected on the plane of Neptune's orbit and a little foreshortened, which apparently brings its perihelion farther in. At the points where they appear to cross, Pluto is high above Neptune. The orbits are nearest at point A where the distance is 2.6 astronomical units (240,000,000 miles). This looks considerable, but when compared—as it should

be—with the distance from the sun, it turns out to be by far the closest approach among any of the principal planets—when the two planets are nearest their distance from one another is only one twelfth of the average distance from the sun, while at the next closest approach between the earth and Venus this fraction is about three tenths.

Such close approaches are, however, very rare. The period of Neptune is 164.77 years, that of Pluto according to latest calculations is 249.17. (The computers, however, point out that on account of the observational errors this value "is determinate to about a year" and we must not draw conclusions from the last two figures.)

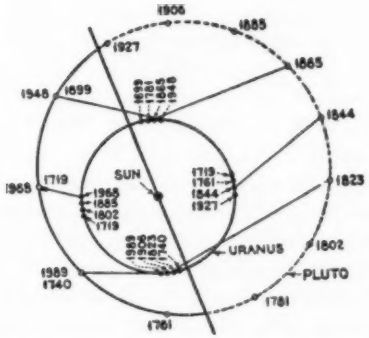

Fig. 2.—Neptune's orbit coincides with the plane of the paper, that of Pluto being inclined 17° and intersecting that plane in the "line of nodes." The dotted part is below the paper, the full part above. Thus the orbits are not "grade crossings" and the danger of collision between the bodies vanishes.

Three revolutions of Neptune require 494.3 years. Two of Pluto take 498.3 years. The relative positions of the planets, therefore, almost repeat themselves at intervals of little less than 500 years. Just how they do it can be seen from Figure 2. The positions of Pluto are marked for 12 equidistant intervals, from one perihelion to the next, at intervals of 20.76 years, and also those of Neptune at the same dates. After eight intervals Neptune has completed a circuit of his orbit and advanced a little less than

three degrees farther, which explains why the dots representing his positions are arranged in pairs. It appears from the figure that the two planets were nearest in 1892, and that at present Neptune

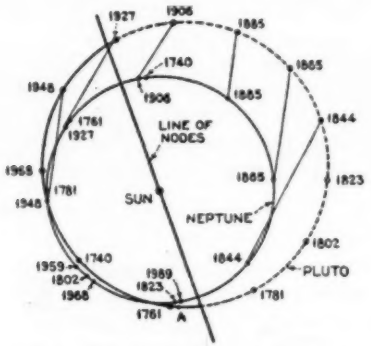

Fig. 3.—Relative positions, 1699-1989.

is drawing more and more ahead of Pluto and increasing the distance between them. For more than two centuries the planets will get farther and farther apart, and it will be nearly 500 years before they are as close again as they were recently. "A stern chase is a long chase" and a simple calculation shows that, on the average, Neptune catches up with Pluto once in 486 years, during which interval one planet has made almost three revolutions and the other almost two.

At the recent conjunction, however, the distance of the two planets was 19 astronomical units—more than six times the minimum, and the perturbations, though greater than for centuries past or to come, must have been relatively small. When may we look for a really close conjunction?

A glance at the figure shows that Neptune passed the critical point of its orbit in 1824 and will do so again in 1989, while Pluto reached the corresponding point in 1763 and will do so again in 2012. On the latter occasion Pluto will still have 23 years to go when Neptune reaches the point of approach and, as Figure 2 shows, the planets will be a long way apart. Five centuries earlier

Neptune came to the same spot in 1495 and Pluto in 1514, this time only 19 years behind. Working backward in this way we find the conjunctions closer and closer at each interval of five centuries, until in the year 976 B.C. the calculated times for the two planets agree within a few months. Still longer ago Neptune was behind Pluto and the conjunction less close.

In the future, the successive "returns" of this conjunction will be less and less favourable but, working forward from 1824 when Pluto was 61 years ahead of Neptune and remembering that the former loses four years in every 494, we find that another close conjunction will occur about the year 9238 A.D. Still others will follow at intervals of about 10,200 years.

These figures, however, are liable to alteration if the true period of Pluto turns out to differ somewhat from that here assumed. If, for example, it were one year longer Pluto would fall behind by six years instead of four in three revolutions of Neptune and the dates of close conjunction would be 11 A.D. and 6765 A.D.; while if Pluto's period should be one year shorter the dates would be near 4000 B.C. and 17,000 A.D. and the interval between close conjunctions fully 20,000 years.

In any case it is clear that no conjunctions of the sort will occur until the span of recorded human history is doubled.

When they do happen the planets are close together for half a century or more, as appears again from a study of the figure. Though the orbital velocity of Pluto is on the average considerably less than that of Neptune, it increases so much at perihelion that for a short time the planet of longer period is actually moving faster and the two bodies keep near one another for almost half a revolution.

At such a time the mutual perturbations must be large, but it will be long enough in all conscience before they can be used to find the masses. Uranus and Pluto also come close to commensurability of periods, for the former completes its revolutions in 84.02 years and three times this is only 2.9 years greater than one revolution of Pluto. The planets therefore return to almost the same relative position after 250 years—during which interval Uranus catches up with Pluto twice.

Figure 3, which is very much like the last one, shows the

positions of the planets. At the last conjunction in 1853 the distance of the planets was 30 astronomical units—about the greatest possible. At the next, in 1965, the distance will be only half as great. The perturbations then will be much larger than in the last century and should lead to a fairly good determination of Pluto's mass.

REVIEW OF PUBLICATIONS

Planisphere for the Northern Hemisphere, prepared by J. Klepesta and published by the Czech Astronomical Society, Prague, Czecho-Slovakia.

This planisphere is of the well-known type, is 12 inches square and is drawn for latitude 40°N. The stars and the graduations are in white ink on a black ground, and can be read easily. The distinguishing feature is that the boundaries of the constellations are according to the decision of the International Astronomical Union at its meeting in 1925 and as delimited by Delporte in the Report of Commission 3. Stars down to mag. 5 are included and variables, nebulae and clusters are indicated.

On the back is an excellent map of the moon by Karel Andel. It is 10½ inches in diameter, is printed in light brown with the names in black.

The planisphere is artistically made, simple and attractive. The present writer would suggest that a label giving instructions for use might be pasted on. Such would be necessary for anyone who had never used such an instrument before. The label might be in the language of the country where it is used. This publication is another creditable production by the Czech Astronomical Society.

C. A. CHANT.

Etoiles et Atomes par A. S. Eddington. French translation by T. Rossignol. 197 pages, 5½ × 9 inches. Paris, Hermann et Cie. Price, 35 francs. 1930.

There could not be any more interesting book than this translation of four of Eddington's lectures followed by two appendices, one on the companion of Sirius and the other on the identification of the nebulium lines.

All the modern problems of astrophysics are treated in it, such as the internal constitution of the stars, the ionization of atoms, the relation between mass and brightness among the stars, the discovery of exceedingly dense stars, the interpretation of stellar

spectra, inter-stellar clouds, the story of Betelgeuse, the pulsating stars, etc.

Four lectures are contained in the book, the fourth one not being in the English edition of Eddington's famous book, but having constituted the second lecture broadcast by the British Broadcasting Corporation.

These lectures are presented in a simple way without mathematical symbols and they constitute fascinating reading for anyone well versed in the French language.

F. HENROTEAU.

Four Books Published by Librairie Scientifique Hermann et Cie, Paris; all 6½ × 10 inches; 1930.

1. *Introduction à l'Étude de la Mécanique Ondulatoire* par Louis de Broglie. 292 pages, 85 francs.

The purpose of this work, from one of the founders of the new conception of wave mechanics, is to show how one passes from the classical conceptions to the newer developments, and to explain why these developments have led to a modification of our general conception of physical laws.

The book opens with a concise summary of the laws of classical mechanics, in which points involved in the recent developments are specially stressed. Then follows the demonstration of the fundamental idea of wave mechanics, *i.e.*, that, with any corpuscle moving with uniform motion in a straight line, it is possible to associate the propagation of a plane monochromatic wave, thus giving the author's ideas of the correspondence between waves and corpuscles. To enable a generalization of these notions to be made, a survey of the general laws of propagation of waves is given in Chapter IV; the general equation of propagation of the waves associated with a material particle can then be derived. An interpretation of the amplitude of these waves is possible using the analogy between classical mechanics and geometrical optics; this interpretation can be retained when geometrical optics is relinquished in favour of physical optics. Experimentally, we have the verifications, by G. P. Thomson and others, of the wave-nature of the electron; these experiments are discussed fully in Chapter VII.

A probability interpretation of the wave functions is now

possible (Ch. IX), but at the same time the concept of definite trajectories for electrons must be abandoned. In fact, these considerations lead to the famous "uncertainty relation" of Heisenberg (Ch. XI) and the associated implications of limited possibility of measurement.

The extension of the treatment to problems involving systems of electrons is made in Chapters XIV, XV, and the new rules of quantization involved in the Schrödinger mechanics are developed (Chs. XVI-XVIII).

Finally the book gives a brief account of the probability interpretation of the general wave function and its connection with the matrix mechanics of Heisenberg, Born and Jordan (Ch. XIX).

2. *Recueil d'Exposés sur les Ondes et Corpuscules* par Louis de Broglie. 82 pages, 20 francs.

This is a collection of five lectures and articles given by the author since November, 1927, *viz.*:—

Modern physics and the work of Fresnel.

Waves and corpuscles in actual physics.

Recent crisis in Undulatory Optics.

Electrons can show interference phenomena.

Determinism and causality in contemporary physics.

They are general semi-popular expositions of various phases of the development worked out in detail in the preceding work. To the person familiar with this development these articles form a good review, but, in the nature of the case, they form a discontinuous series which is a little unsatisfactory to the general reader.

3. *Conférences d'Actualités Scientifiques et Industrielles*, under the auspices of the Conservatoire National des Arts et Métiers. 272 pages, 35 francs.

This is a report of nine contributions by prominent scientists covering a large field of recent developments, with an introduction by Jules Lemoine.

(1) L. de Broglie: The Recent Crisis in Undulatory Optics. (This lecture is one of those referred to above.)

(2) G. Foex: Mesomorphic Substances, their Magnetic Properties. Mesomorphic substances are those which show physical properties intermediate between the crystalline state and the isotropic: they are anisotropic, show birefringence but have not the degree of

symmetry displayed by crystals. Two graduations of mesomorphic substances are distinguished, *viz.*, smectic (as for soaps) and némátic. When a body can assume different states, they change with increasing temperature in the following order: from crystalline to smectic to némátic to isotropic.

Various experimental results on the effect of a magnetic field on these states tend to throw light on the arrangement of atoms in a crystal structure.

(3) Eugène Bloch: Atoms of Light and Quanta.

This is a fairly short readable review of the development of quantum ideas from Planck to Heisenberg. Reference is made to contributions of Einstein, Bohr, A. H. Compton, de Broglie, and G. P. Thomson, leading up to Heisenberg's indeterminism.

(4) L. Dunoyer: The Photoelectric Cell and its Applications.

The paper opens with a description of the manufacture of these cells and how the characteristics of the cell depend on the metals used and the incident light. This is followed by methods of measuring the photoelectric current, (i) Direct method by string electrometer, and (ii) Methods of amplification by use of electron tubes.

The third section deals with the following practical applications: (i) photometry; (ii) Opacity measurement; (iii) measurement of reflecting power; (iv) colorimetry; (v) measurement of time for photographic exposure; (vi) talking moving pictures, photo-telegraphy and (vii) television.

(5) G. Ribaud: Radiation from Incandescent Bodies, Temperature Measurement of Brilliance, Radiation and Colour, Pyrometry.

The laws of radiation are developed and useful tables of emissive powers, relations between the temperatures of brilliance—the true temperature—and the relation between colour temperature and true temperature are given.

(5) Lieut.-Colonel Jullien: Applications of the electric current, of Radio Oscillations and Photoelectric Phenomena to the Development of Instruments of Music.

Beginning with the Telharmonium of Cahill (1900) the author describes some twenty types of these methods of producing music. The article ends with a section on the future of electrically-produced

music. This development offers possibilities beyond the range of orchestral instruments, but it will be a long time before it will replace the individual instruments with which we are familiar.

(6) Léon Bloch: The Structure of Spectra and the Structure of Atoms.

A fairly short paper on the relation of spectral series to the theories of the structure of the atom.

(7) V. Kamerer: High Vapour Pressures.

In the words of the author: "In the lecture I shall attempt to recall briefly the technical ideas that form the basis for utilization of vapours for the production of motive power and which justify the use of high pressures. I shall then try to give a short review, in so far as generators are involved, of the present state of the construction, and the tendencies which will influence engineers in the future."

(8) R. Mesny: Direction Wireless and its Applications.

The paper opens with a theoretical treatment of the electromagnetic action of various forms of antennae arrangements and cites the practical applications which are found in (i) the Beam System; (ii) the S.F.R. (Soc. franc. radioel.); and (iii) the Telefunken. The various applications are given, ending with the suggestion that "wireless beam" lighthouses are now quite a possibility.

4. *L'Électro-Acoustique: Rapports de l'Acoustique moderne et de l'Electricité*, par Pierre David. 40 pages, 5 francs.

This is a lecture delivered at the Conservatoire des Arts et Métiers on May 9, 1930. It deals with problems in phonometry and analysis of sounds, the reproduction of sound, and the study of the quality of complex musical sounds. In the main it is a presentation of experiments which have been carried out during the last fifteen years in the laboratories of the Bell Telephone Co. in New York City. In general, sound vibrations may be translated into electrical vibrations and amplified as a whole; any portion can be suppressed by means of electrical filters and the remainder again amplified so as to enable one to study details of frequency and intensity—experiments which were quite impossible before the advent of the electron tube.

E. F. Burton.

NEWS AND COMMENTS

On the invitation of Professor Frank Schlesinger, the American Astronomical Society is holding its forty-fifth meeting at Yale University, New Haven, Conn., December 31, 1930, to January 3, 1931. Those attending will have opportunities to visit the Observatory and inspect the university buildings and collections. In regard to the "Appointment Service" of the Society, Secretary Dugan makes the following statement: "Several positions of rather modest emolument were still open at last reports. The secretary wishes to make natural protest against a natural neglect to advise him when a position is filled or secured. This has resulted in much unnecessary correspondence, recommending men after they are placed and advising application for positions already filled. The neglect is thoughtless and reprehensible"! He reminds members of their opportunity to offer suggestions to the nominating committee: Messrs. Chant, Stetson, Fox, *chairman*. A committee of the Society is still considering the question as to whether the Society should publish a journal (perhaps taking over one already in existence), and the question is to be submitted to Council at the coming meeting.

Under the auspices of the Astronomical Society of the Pacific and the Mount Wilson Observatory, the following very interesting illustrated lecture course on astronomy will be given during the coming winter, both at Pasadena and Los Angeles: "What the Stars are Made of", Dr. Arthur S. King, Mount Wilson Observatory; "Taking the Census in the Solar System", Dr. Seth B. Nicholson, Mount Wilson Observatory; "Comets and Asteroids", Dr. William F. Meyer, President, Astronomical Society of the Pacific; "Celestial Laboratories", Dr. Theodore Dunham, Jr., Mount Wilson Observatory; "The Exploration of Space", Dr. Edwin P. Hubble, Mount Wilson Observatory.

The American Astronomical Society has formed a committee of twenty to proceed with the necessary organization for the meeting of the International Astronomical Union which is to be held in

Cambridge, Mass., beginning as soon as practicable after the total solar eclipse of the sun on August 31, 1932. The selected executive committee consists of E. W. Brown, W. W. Campbell, R. S. Dugan, Frank Schlesinger, Harlow Shapley, Joel Stebbins and H. N. Russell, and several sub-committees have been appointed. (*Popular Astronomy.*)

The American Association for the Advancement of Science is holding its annual meeting at Cleveland, Ohio, on December 29, and days following. The retiring president, Dr. Robert A. Millikan, will deliver the main lecture of the meeting at the opening session on Monday evening in the Cleveland music hall on the subject "Atomic Disintegration and Atomic Synthesis". The Astronomy Section will meet for the presentation of papers on Tuesday, December 30, in the Case School of Applied Science, the building made famous by the original Michelson and Morley experiments on ether-drift and the later observations of Professor D. C. Miller. On Wednesday afternoon, the retiring vice-president of Section D (Astronomy), Dr. Harlow Shapley, will give an address on "Galactic Exploration". Visiting astronomers will also be interested in the Municipal Observatory, and the Warner and Swasey plant where the mountings of many of the world's largest telescopes were designed and built.

REDEL.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

A Geologist Philosophises

At the annual meeting of the Australasian Association for the Advancement of Science, President E. C. Andrews, Government Geologist, gave a comprehensive address on "The Philosophical Significance of Science and History", from which the following extracts are made:—

If the sight of an Alpine meadow, or of a golden sunset, fills the beholder with certain emotions, leading to an influence on life's activities, even temporarily, there must be something left for examination, some residuum even after the explanation has been vouchsafed that the brilliance of the picture was due to the action of light, which consists of so many undulations a second, otherwise the Universe must be supposed either to produce something out of nothing, even if it be only mere intellect, or else it must be referred to a transcendent activity, working through but from outside the Universe itself. The light vibrations are in the picture, but their number does not even explain to us why light moves 3×10^{10} centimetres a second, nor does it explain the emotional and intellectual activities aroused.

. . . . . .

Notwithstanding the grandeur of the Galaxy, and the extra-galactic nebulae, with their aggregated thousands of millions of suns or stars, and the incredible size, weight, luminosity, radiation, and energy of each individual star, it is really the immensity of space, as revealed by the arrangement of the stars which impresses the observer. From the calculations of Hubble, Jeans, and others, the idea is gathered that, if matter were distributed uniformly through space, it would be as if some activity had placed one tiny speck of dust in each of a vast series of cubes all in contact with each other, each cube being of 80 miles width—that is to say, each tiny particle or speck, individually invisible to the naked eye, would be eighty miles distant from its nearest neighbour speck. Nor is this all, for the study of atoms themselves from which our hypothecated specks of dust are composed, one only in every 80-mile cube of space, suggests that so-called "solid matter" appears to occupy less than one million millionth of the dimensions generally supposed to be occupied solidly. The remainder apparently may be considered as space, or emptiness. How great are our misconceptions! In what figures of speech do we indulge when exalting our mundane works and neglecting the consideration of man's gigantic setting of space, energy, time, and law! We speak also of the Universe, meaning the stars, the tiny specks, which only reveal the magnitude of their setting, and indicate the part for the whole.

AUDIBILITY OF THE AURORA

In a 30-page pamphlet recently published, James Halvor Johnson, of San Mateo, Cal., discusses the altitude and the audibility of the aurora. In a paper in the *Publications of the Astronomical Society of the Pacific*, December, 1927, he reported some observations which he had made while a resident in Alaska, and his results were referred to in this JOURNAL (Vol. XXII, p. 28, 1928). He now gives further information, secured chiefly in response to a request printed in about twenty newspapers in Alaska and the Yukon Territory. Twenty-three replies, written by persons in various walks in life, give much more positive evidence of sounds accompanying some auroral displays.

In this JOURNAL, Vol. XVII, p. 273, 1923, the present writer printed statements from a considerable number of observers who said they had heard sounds, and the conclusion was reached that in some brilliant displays sounds have been heard. There was so much positive evidence that it seemed impossible that all the observers could have been deceived. It was remarked that the immediate source of the sound could not be where the display was located in space since it had been shown that usually it was seventy miles or more distant, but it was suggested that it was an effect of electrostatic induction. The present writer is pleased to see that his views are similar to those of Professor Störmer, of Oslo, Norway, who has made practically all of the unquestioned measurements of the height of the aurora. In *Nature* for January 8, 1927 (quoted by Mr. Johnson), Störmer says:—

Aurora, October 15, 1926, near Oslo. But what was of preponderant interest is the following fact: When, with my assistant at 19 h 15 m, Greenwich Civil Time, I went out of the observatory to observe the aurora, the latter seemed to be at its maximum. Yellow-green and fan-shaped, it undulated from above, from zenith downwards—and at the same time both of us noticed a very curious faint whistling sound distinctly undulatory, which seemed to follow exactly the vibrations of the aurora. The sound was first noticed by me, and upon asking my assistant if he could hear anything he answered that he noticed a curious increasing and decreasing whistling sound. We heard the sound during the ten minutes we were able to stay outside the observatory, before

continuing our observations—(Signed, Hans S. Jelstrup). Then Störmer adds: To the above most interesting communication from Mr. Jelstrup I may add the following:. . . .During the period from 19 h 15 m to 19 h 25 m, when Mr. Jelstrup heard the whistling of the aurora, I regret that no successful photograms were taken. . . . .It seems to me probable that the sound which, as Mr. Jelstrup says, exactly followed the vibrations of the aurora, could not come directly from the latter but from the surroundings, trees, antennae, and so on, and were caused by electrostatic discharges, which in their turn were caused by influence from the varying electrostatic charges of the aurora overhead.

A New Sort of Meteorite

A farmer near Perkasie, about 30 miles from Philadelphia, heard a roar, a whistling sound and then saw a cloud of dust rise as something struck the ground, and naturally thought he had seen a meteorite fall; but it turned out to be a wrench dropped from an airplane at a great height.

A Great Memorial

The important announcement has just been made that in the near future there will be established in the vicinity of Toronto an astronomical observatory which will rank with the world's greatest institutions of this sort. It will be erected by Mrs. D. A. Dunlap and her son, D. Moffat Dunlap, as a memorial to the late David A. Dunlap, who died on October 29, 1924, and will be known as the David Dunlap Observatory.

Astronomy and geology were both favourite studies of Mr. Dunlap, but the former had a peculiar attraction for him. He was a keen student of the heavens and always liked to share his knowledge with others. This project has been under consideration for the last five years and will now be brought to completion. In working out the plans Mrs. Dunlap has had the assistance of Professor C. A. Chant, head of the Department of Astronomy of the University of Toronto.

The outstanding feature of the observatory will be a large

reflecting telescope seventy-four inches in diameter. There is only one of greater aperture in the world, namely that on Mount Wilson in California. The instrument was ordered some time ago from the firm of Sir Howard Grubb, Parsons and Co., Newcastle-on-Tyne, England. It will be housed in a circular metal building, such construction being best for this purpose. The observatory building will be a beautiful structure in the classic style. It will be erected on a suitable site near Toronto in the midst of a large acreage which will be converted into a park to be known as the David Dunlap Park.

When the observatory is completed it will be under the Department of Astronomy of the University of Toronto, while the park will be developed in a scientific way by the Faculty of Forestry.

The new institution will bring distinction to the university, the city, the province and indeed the whole dominion. It will be an enduring memorial to a worthy citizen.

Note.—The above announcement was made public on December 30, 1930. A great observatory in the midst of a fine park will be an appropriate memorial to the late Mr. Dunlap, and it will likewise be a splendid gift to the university and the community. Further information will be given as the project is carried out.

C. A. Chant.

MEETINGS OF THE SOCIETY

AT OTTAWA

October 31, 1930.—On this evening, the Ottawa Centre held their first regular meeting of the season in the Victoria Memorial Museum. The president, Mr. C. C. Smith was in the chair.

After welcoming the members and friends, and giving a description of the origin of the day, Hallowe'en, Mr. Smith introduced the speaker, Major L. T. Burwash, F.G.S.C., Arctic investigator of the North West Territories branch, Department of Interior, Ottawa. Major Burwash chose "Arctic Explorations" as the topic of his address.

Having spent twenty-three years exploring the Arctic shores and the northern plains of Canada, Major Burwash is well qualified to deal with such a subject.

The lecturer commenced by explaining that the four different groups into which Arctic investigators may be classified are:—(1) Those who went from an economic point of view, that is, to find a shorter passage by means of the Arctic Ocean; the first such expedition was in 1602. (2) Those in search of that point of the earth called the pole. (3) Those whose interest was to study the people of these northern parts and assist them where possible. (4) Those who go to discover the natural resources of the country and with the intention of putting them on a money making basis.

The class in which Major Burwash was working was the third. This class is of most interest to the Government, and it was thus the lot of the lecturer to travel in the north with the primary object of studying the native peoples of Canada within the Arctic circle, and the resources upon which they exist, and hence to learn what protection they must be given against the wave of civilization which each year comes closer to them.

Since more than one-third of the land of Canada lies within what is known as the North West Territories, it seems natural that the resources of this vast area might be of great importance to our country. However, in exploiting any resources there it must be remembered that the nearest railway ends 300 miles from the southern boundary of the Territories and therefore any resources have to be extensive enough to overcome this necessarily added expense of transportation before they can be marketed.

The resources of these regions fall into two classes, those which relate to the existence of the people, namely, fish, sea mammals, fur-bearing animals, game, etc.; and, secondly, those which have to do with the economic development of the territory, namely, timber, oil, minerals, etc.

As well as the primary object of his investigation, Major Burwash has had many other duties to perform on his many northern expeditions. To mention a few: study of geology, mineral resources, meteorological observations and a

study of the behaviour of the compass near and at the earth's north magnetic pole, which lies on Boothia peninsula.

The results of the latter observations were briefly described, showing that within one hundred miles of the pole the ordinary compass acts uncertainly, but there the dip circle becomes very active, till at the pole it takes up a vertical position.

Last season Major Burwash conducted an aerial survey of the Arctic coast, charting that region and taking aerial pictures of some 2,000 miles of the coast. As a result of this very successful work, it will now be possible to make an accurate map of at least 1,500 miles of Canada's northern coastline.

In comparison with work carried on in former years, when travelling was by dog teams, Major Burwash related one trip which formerly had taken from the middle of May till the beginning of August, and this year he made the same trip by air in eight hours.

During his surveys up north the lecturer gained some valuable information regarding the Franklin expedition of 1855, when 129 officers and men were lost and about whom very little information has since been collected. It had been reported by the natives that Franklin was buried in a certain place and that possibly their log might be found there. It was such reports that took Major Burwash to King William's island last summer, and as a result he was able to bring back some relics of the famous expedition and investigate many reports regarding the fate of these early explorers.

His explanation of the mysterious disappearance of the last remnant of Franklin's men is that this part of the crews of the two ships, after travelling towards the main land for some time turned back and reached their ships again and that both ships foundered carrying the crews with them.

At the conclusion of his address, Major Burwash showed a number of slides depicting the different types of natives inhabiting the regions, and pictures of the relics found by him of the Franklin Expedition.

In closing the meeting, Mr. Smith thanked the lecturer on behalf of the society for his most interesting lecture.

November 28.—On this evening the second open meeting of the season was held in the lecture hall of the Victoria Memorial Museum.

After a few words of welcome, Mr. C. C. Smith, the president, introduced the lecturer, Miss A. Vibert Douglas, M.B.E., Ph.D., of McGill University. The subject of her lecture was "Jeans and Eddington". Having studied under Sir Arthur Stanley Eddington, and having heard Sir James Hopwood Jeans, and having read many of their works, Miss Douglas is well fitted to discuss these two brilliant thinkers.

Some months ago Miss Douglas delivered this lecture to the Toronto Centre and an account of it has already been published in THE JOURNAL for May-June, 1930, page 245.

At the close of the meeting, the president thanked Miss Douglas for coming to Ottawa and giving this very enjoyable and educative lecture.

M. S. BURLAND,
Secretary, Ottawa Centre.

AT TORONTO

November 4.—A regular meeting was held in the Physics Building of the University of Toronto, on Tuesday at 8 p.m.; Mr. J. R. Collins in the chair. There were two elections to membership:—

Ray Lee Defries, 746 Randolph Building, Memphis, Tennessee.

Lawrence Braymer, Holicong, Pennsylvania.

The chairman referred to the coming opposition of Eros, which will provide data towards a new determination of the sun's parallax. Mr. M. S. Groh gave an interesting description of the constellation Aquila.

The speaker for the evening was Mr. R. Meldrum Stewart, M.A., and his subject "Geophysics at the Dominion Observatory". The lecturer reminded his audience that geophysics embraces many subjects, but for the present purpose only three aspects would be considered, namely, the magnetic needle and its variations, gravity, and seismology. Slides were used throughout the lecture which materially assisted those present to understand the various instruments and methods employed in the quest for knowledge upon these subjects. One instrument depicted had been used in many sections of the Dominion to measure the changes in the magnetic dip, which varies from place to place. The study of the deviations of the magnetic needle from the true north is very intricate and important, these deviations are not constant but are always changing, hence the necessity for exact and up-to-date information, which is supplied to mariners and others interested. From Hudson strait to the Mackenzie river basin there is about 85 degrees difference in the declination of the compass, and the trend, which was formerly eastward, is now mainly westward. Little is known of the underlying causes for this change, which is even of a daily occurrence in some sections, but it was shown, by a graph of the sunspot curve, that apparently the changes in the amount of disturbance on the sun correspond in some degree to the variations of the needle.

The Ottawa Observatory makes observations in many places throughout Canada to obtain records of these variations. An interesting slide was shown of a building in Ottawa, designed especially for this purpose, the nails or other hardware used in its construction being composed entirely of brass or copper.

Gravitational force is usually determined with the aid of pendulums, the period of each swing determining the amount of pull of the earth. Great care is taken in the preservation of these instruments, it can easily be appreciated that even a speck of dust attached to one of these pendulums would affect the calculations. The lecturer pointed out that gravitational force is stronger at the poles than at the equator, due to the longer radius at the latter.

Slides were projected of several types of seismographs, which record and measure the waves emanating from earthquakes and enable observers to determine their direction and distance.

In proposing a vote of thanks to the speaker for his instructive lecture, Prof. C. A. Chant referred to the work of the Dominion Observatory, which is not confined to Astronomy alone, but embraces many other branches of scientific enquiry, as the present lecture would show. The motion was seconded by Mr. A. F. Hunter.

S. C. Brown, *Recorder.*

The Royal Astronomical Society of Canada

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THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

The Astronomical and Physical Society of Toronto was incorporated in 1890, though it had existed some years before this; in 1900 it became The Toronto Astronomical Society; and on March 3, 1903, it was given permission to use the name, The Royal Astronomical Society of Canada.

Its objects are to study astronomy and cognate subjects, to publish the results of its work, and to maintain a library.

For many years the Toronto organization existed alone, but now the Society is national in extent, having active Centres in Montreal, P.Q.; Ottawa, Toronto, Hamilton and London, Ont.; Winnipeg, Man.; and Victoria, B.C. Among its 800 members are a number of leading astronomers and scientists of the world, many amateurs, and, in addition, many laymen who are interested in the culture of the science.

The Society publishes a monthly JOURNAL containing each year about 500 pages of interesting articles and a yearly OBSERVER'S HANDBOOK of about 80 pages, containing valuable information for the amateur observer. Single copies of the JOURNAL or HANDBOOK are 25 cents.

Membership in the Society is open to anyone interested in astronomy. Annual dues, $2.00; life membership, $25.00 (no further dues). Publications are free to the members, or may be subscribed for separately.

Extract from the By-Laws: Candidates who are elected to membership will be attached to a particular Centre, or to a section known as *Members at Large*. Members of the Society who live outside of Canada, or in a province in which there is no Centre of the Society will be considered *Members at Large* and not attached to any particular Centre, unless these members are expressly nominated for membership and attachment to a particular Centre. Members may be transferred from one Centre to another, or to the section *Members at Large* by the Council of the Society if written application for such transfer is made by such member to the Council.

The library and offices of the Society are at 198 College St., Toronto, Ont. Applications for membership or for further information should be addressed to a local secretary (see back of this page) or to the General Secretary at the above address.